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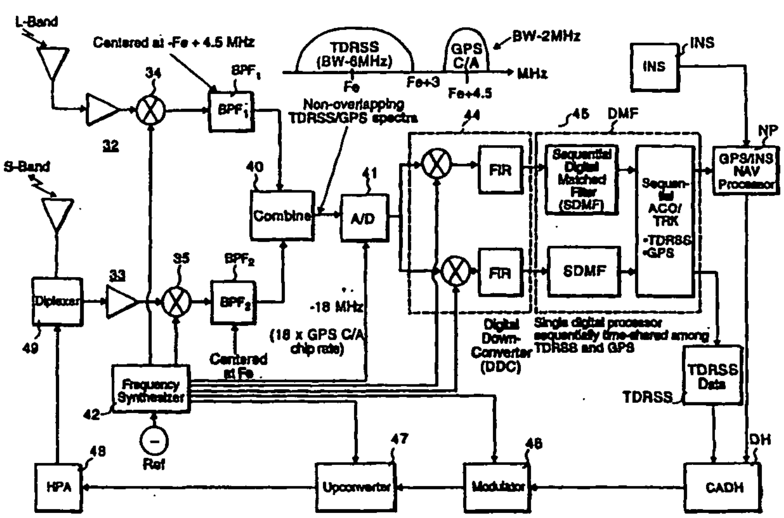

(57) Abstract

A communications system operating in one or more frequency bands (L and S) of various number of channels per band. The system comprises an antenna and RF front end (32 or 33) for each band, a separate RF to IF down converter for each band, an analog–to–digital converter (41) converts analog signals to digital signals from a combiner (40), a digital down converter (44) converts the digital signals to baseband signals and a single digital processor (45) sequentially time shared among all the bands and channels. The IF for each band is centered at a succession of frequencies f_0 such that the spectra for each band are non–overlapping, with the center frequency. An analog–to–digital converter sampling rate is chosen such that one band is centered at baseband, and one or more other bands are centered at a specific relationship with the sampling rate such that each band is individually down converted to baseband by appropriate selection of tap weight multiplying sequences.

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MULTI-BAND, MULTI-FUNCTION INTEGRATED TRANSCEIVER

REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Serial No. 08/736,110 filed October 24, 1996 entitled A SYSTEM FOR INCREASING THE UTILITY OF SATELLITE COMMUNICATION SYSTEMS which, in turn, is a continuation-in-part of application Serial No. 159,410 filed November 19, 1993 entitled SYSTEM FOR INCREASING THE UTILITY OF SATELLITE COMMUNICATION SYSTEMS, now U.S. Patent No. 5,572,216, both of which are incorporated herein by reference. This application is also the subject of provisional application Serial No. 60/087,689 filed August 24, 1998.

BACKGROUND AND BRIEF DESCRIPTION OF THE INVENTION

In Figure 1 of the above-referenced application and patent, a low power transceiver is disclosed (the Figure shows only the receiver portion) in which a transmitter and receiver operate non-coherently, that is, without the requirement that transmitted and received signals bear a fixed electrical frequency and phase relationship so that as a result, the transceiver can be simple and robust and

of lower power consumption. One such embodiment integrates a GPS receiver into an existing primary two-way communications system, which accomplishes position location for its user. Moreover, the resulting position location could be caused to be transmitted automatically or on signal from any other transceiver or ground location using the primary link.

The present invention provides wireless communications capability, for either terrestrial or space based operations, involving the simultaneous processing of multiple communications signals and types, received from various and multiple bands, such as an integrated TDRSS/GPS satellite receiver, as well as numerous other waveform and frequency band combinations. The key features of the transceiver are that it is multi-channel/multi-band, leverages ongoing transceiver technology, is low power, is applicable to both spread and non-spread signals (i.e. applicable to a much broader range of users) and provides high performance, rapid acquisition/reacquisition and tracking in a single digital processing path.

Applications of the invention include integrating GPS into a receiver primarily using another communications link, thus providing receiver position and time across that link; among others, tracking and telemetry for launch vehicles (i.e., range safety) using TDRSS/GPS is a prime example of this. Other applications include integrated

GPS/GLONASS, multi-mode analog/digital cellular, integrated NASA/Government communications links (i.e., TDRSS, GN, SGLS, etc.).

The invention is directed to communications system operating in one or more frequency bands comprising a various number of channels per band (for a total of N channels), and transceiver means for receiving these multiple bands of signals characterized in that the transceiver comprises a system of antenna and RF front end for each said band, a separate RF to IF downconverter for each said band, said IF for each band centered at a succession of frequencies F_c such that the spectra for each band are non-overlapping, with said center frequencies and analog-to-digital converter sampling rate chosen such that one band is centered at baseband, and one or more other bands are centered at a specific relationship with the sampling rate such that each band is individually downconverted to baseband by appropriate selection of tap weight multiplying sequences (such as alternating +/- sequence for the case of F_c equal to one-fourth the sampling rate), combining means for combining said RF signals, analog-to-digital converter means for converting analog signals to digital signals from said combining means, digital downconverter means for converting said digital signals to baseband signals and a single digital processor sequentially time shared among all said Bands and channels,

a signal processor connected to said single digital processor responsible for any final signal and/or data processing or formatting, and a signal transmitter of unspecified design details, coupled into the said transceiver antenna path by means of a diplexer device.

Further, the invention also features a tracking and data relay satellite system operating in the S-band (TDRSS) and in conjunction with a GPS satellite system operating in the L-band, and transceiver means for receiving L-band and S-band characterized in that the transceiver comprises a system antenna and RF front end for each said S-band and L-band signal, a separate RF to IF downconverter for each said S-band and L-band signal, said IF for said S-band signal operating at a frequency F_0 and said IF signals for said L-band operating and centered at a frequency F_0 plus a predetermined separation frequency so that the spectra for said S-band and the spectra for said L-band are non-overlapping, combining means for combining said IF signals analog-to-digital converter means for converting analog signals to digital signals from said combining means, digital downconverter means for converting said digital signals to baseband signals and a single digital processor sequentially time shared among said S-band and L-band signals, respectively, a GPS navigation processor and a TDRSS data processor connected to said single digital processor, a TDRSS (S-band) signal transmitter of

unspecified design details, coupled into the said TDRSS (S-band) transceiver antenna path by means of a diplexer device.

Furthermore, invention also features a multi-Band, multi-channel digital matched filter (DMF) implementation comprising multiple sets (N) of PN-Generators and storage means for maintaining N sets of tap weights within the DMF, N-stage data delay line which shifts the digital data samples down the line at the baseband sampling rate, arithmetic circuitry for multiplying alternate taps of said delay line by one of the stored sets of tap weights, pre-multiplied by the +/- or other appropriate downconversion sequence, and summing each of said products, to form a correlation output sample that is a member of the sequence corresponding to a the channel represented by the selected tap weights; sufficient consecutive such sum-of-products samples are thus formed to form the complete correlation epoch function corresponding to the selected channel, whereby during acquisition, the tap weights for a single channel are manipulated appropriately such that consecutive DMF output samples represent correlation epochs associated with a particular PN alignment (offset), and thus an acquisition detection circuit can observe which of the correlation alignments is of sufficient magnitude to indicate the correct PN alignment, and thus transition that channel into tracking, and during tracking, the tap weights

are alternated between various channels and manipulated appropriately such that the output sequence from the DMF thus consists of a sequence of sum-of-products samples that are in fact also a sequence of correlation epochs corresponding to each of the channels being tracked, and during ongoing operations in fact both acquisition and tracking operations among multiple channels may be simultaneously taking place using the said techniques.

DESCRIPTION OF THE DRAWINGS

The above and other objects, advantages and features of the invention will be more apparent when considered with the following specification and accompanying drawings wherein:

Figure 1 illustrates the primary novel receiver concept disclosed in this invention, which is the incorporation of multiple signal channels originating from multiple signal bands into a common integrated digital processing path (each band could also function as a transceiver, by adding commonly understood transmitter logic and coupling into the appropriate receiver antenna using a diplexer),

Figure 2 is a TDRSS transceiver incorporating a GPS receiver which can accomplish position location -- essentially an expanded version of Figure 4 of Patent No. 5,572,216,

Figure 3 is a block diagram of one preferred embodiment of the transceiver illustrating an integrated TDRSS/GPS transceiver according to the invention,

Figure 4 discloses a digital matched filter (DMF) for the I or Inphase channel (identical Q or Quadrature channel not shown),

Figure 5 is a block diagram of a sequential digital matched filter (SDMF) for the Inphase (I) channel shown, illustrating the time sequential correlation epochs that appear at the DMF output for the multiple tracked signals,

Figure 6 is a chart showing the spectra separation of the GPS/TDRSS embodiment after the analog signals have been combined,

Figure 7 is a schematic illustration of a digital matched filter computational cycle for the example GPS/TDRSS embodiment,

Figure 8 is an illustrative allocation of a cycle of N clock ticks according to the invention for the example GPS/TDRSS embodiment, and

Figure 9 is a functional illustration of a feed forward sequential tracking algorithm incorporated in the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the receiver shown in Figure 1, a B-band, N-channel receiver is disclosed having functional antennae A-1....A-B

coupled via amplifiers to corresponding RF/IF converters 10-1....10-B which are supplied from corresponding frequency synthesizers 11-1...11-B which in turn are supplied, preferably, from a common frequency source 12. The IF signals are bandpass filtered in 13-A....13-B and then combined 14, analog to digital converted 15, downconverted 16, and passed to N-channel digital matched filter 17. The output of N-=channel sequential digital matched filter 17 is demodulated in demodulator means 18 and the demodulated signals for the various channels are processed in data handler or processor 19 and supplied to various utilization devices 20-1...20-B.

Referring to Figure 2, the upper portion 22 of the block diagram is an illustration of an example embodiment of the invention, an L-band (GPS) receiver having a separate frequency synthesizer 23 and RF front end 24 with a navigation processor 25 outputting GPS location signals and a separate S-band (TDRSS) processing channel 25 including an RF front end 26 and a separate receiver channel with a separate frequency synthesizer 27 and a separate transmitter channel having its own modulator 28, upconverter 29 and high-powered amplifier 30 feeding a diplexer 31 for transmissions on the S-band.

According to the present invention, the integrated TDRSS/GPS transceiver maintains separate RF front ends 32, 33 and RF/IF downconverters 34, 35 for both the TDRSS

signals, channels and the GPS signal channels (S-band and L-band, respectively). However, according to the present invention, the transceiver has common frequency synthesis 36 and clock reference signals with carefully allocated frequency plans to minimize distinct frequencies and clocks. In addition, the present invention combines the TDRSS and GPS signals from bandpass filters BPF in combining 37 at intermediate frequency (IF) and shares all remaining circuitry to the maximum extent possible. In this way, the TDRSS and GPS IF signals do not spectrally overlap (which thereby avoids signal-to-noise degradation); the TDRSS and GPS IF spectral spacing is carefully selected for efficient digital signal processing. Moreover, the digital baseband processing shares common circuitry so as to enable programmable digital matched filter (DMF) usage, clear or spread modes, and rapid acquisition and reacquisition capability. There is also common sharing of feed-forward tracking and detection for carrier, PN, and symbol timing loops. Finally, it enables a dedicated GPS/inertial navigation processor NP to be incorporated in a small hand-held transceiver unit.

Figure 3 illustrates one preferred embodiment of the invention, for the case of the integrated TDRSS/GPS transceiver. In this embodiment, note that the receiver channel for the S-band is centered at F_0 and that the IF for the L-band is centered at F_0 + 4.5 MHz so that there is non-

overlapping TDRSS and GPS spectra. The output of the combiner 40 is supplied to the analog-to-digital converter 41. A common frequency synthesizer 42 is used to provide frequency synthesis and clock references for the transceiver. Note also that the output of the Analog-to-Digital (A/D) converter 41 is fed to a digital downconverter (DDC) 44 which outputs signals to the sequential digital matched filter (SDMF) 45 in a single digital processor sequentially time shared among all TDRSS and GPS channels. An inertial navigation system INS may also be incorporated in the transceiver for purposes of providing the navigation processor NP with inertial navigation signals. The TDRSS signals to be transmitted, which may include GPS positioning information derived from the receiver, are supplied by data handler DH to a modulator 46, upconverted 47 and supplied to the high-power amplifier (HPA) 48 which feeds the diplexer 49 and transmits the signals on the S-band to the satellite *S*. The circuitry illustrated in Figure 3 is predicated on the following assumptions:

- GPS C/A signal @ L1:

  1575.42 MHz
  1.023 MHz PN chip rate

- TDRSS SSA

  Flexible S-band forward link frequency, F_1.

  Corresponding PN chip rate = $\frac{(31)F_1}{(221)(96)}$.

User forward/return link signals may be spread or non-spread.

Return Link Frequency -- (240/221) F_1.

Noncoherent operation (since GPS is available).

- Users, such as ELV, dynamics warrants rapid acq/reacq receiver (for both TDRSS and GPS).

In regards to the referenced digital matched filter (DMF) shown in Figure 4, note:

- During PN acquisition, DMF essentially provides N-fold parallel processing:

  Yields ~ 2 orders of magnitude reduction in PN code acquisition time (spread cases).

  All DMF output samples used for acquisition.

- During tracking DMF provides on-time, early, late samples:

  All other DMF output samples (i.e., most of N-clock cycle), are unused during tracking.

  This unused time, during tracking, is the basis for the sequential digital matched filter (SDMF).

Sequential digital matched filter (SDMF) illustrated for the I-channel is shown in Figure 5. Note:

- During tracking, distinct PN correlation functions are uniformly spaced (as driven by the PN tracking loops) in time at the DMF output, as shown.

  The full cycle time is used in the DMF, in contrast to the reference DMF (where almost the entire cycle time goes unused during tracking),

- On-time, early, late samples sequentially used by single set of acquisition/tracking hardware/software to track <u>all</u> signals.

- Cycle time can be flexibly allocated to:

  Signal acquisition, or

  Signal acquisition of 1 signal while tracking multiple other signals.

The key features of digital baseband processing include the following (refer to Figure 6):

- Low-pass spectrum after Digital Downconversion (DDC).

- A/D sampling rate is determined by the total bandwidth required for all Bands, plus any desired guard spacing; for the GPS/TDRSS embodiment, the sampling rate = (18)(1.023) MHz (greater than or equal to twice the low-pass composite bandwidth).

  The Nyquist Criterion is satisfied

  The SDMF sequentially processes TDRSS, GPS signals by suitable DMF tap weight settings.

- SDMF processes primary Band (for example, TDRSS) as baseband PN-coded (or clear mode) signal. For the TDRSS example:

  PN: DMF tap weights matched to PN code -- 18 x 1.023 MHz ≈ 6 x TDRSS PN chip rate (note; exactly equals 6 x TDRSS PN chip rate, for 3.069 Mcps and F_1 = 2100.384 MHz).

  Clear mode: DMF tap weights set to all 1's.

  When tap weights set for TDRSS, the other signals (i.e., GPS signals) are filtered out.

- SDMF processes a secondary Band (for example, GPS) as IF PN-coded (or clear-mode) signal. For the GPS example:

  IF @ 4.5 x 1.023 MHz.

  Sampling rate = 4 x IF

DMF tap weights set to GPS C/A code modulated by alternating {+,-} sequence (this effectively downconverts the signals to baseband).

When tap weights set for GPS, the other signals (i.e., TDRSS signals) are filtered out.

- For the case of further secondary Bands, other schemes for weight adjustment (i.e., to effect other than Fs/4 downconversion) may be used; alternatively, actual digital NCO/modulators may be incorporated into the tap multipliers to perform arbitrary downconversion for each Band.

Figures 7 and 8 are illustrative of the DMF computational cycle. For the GPS/TDRSS example embodiment, note:

In regards to Figure 7:

- 18 clock ticks of each DMF cycle spans:

  1 GPS C/A chip

  3 TDRSS PN chips (i.e., 6 clock ticks per TDRSS PN chip)

- Illustrative allocation of cycle of N clock ticks.

In regards to Figure 8:

- N = 354 DMF stages, which supports sequential tracking of 1 TDRSS signal + GPS signals.

- DMF I/O delay ~ 20 μs; accommodates ~ 10kHz uncertainty.

Referring now to Figure 9, a functional diagram of the sequential tracking process is illustrated. In this process, the I/Q early/on-time/late tracking samples coming out of the SDMF are phase rotated (for carrier tracking),

and then formed into discriminators that are used as feedback to the various tracking loops. Additionally, the on-time samples are further integrated and formed into soft-decision data samples. For the case of GPS, various observables contained within both the SDMF and the tracking circuitry are made available to the Navigation Processor for use in computing time and position. Note that the single set of digital processing functionality is sequentially shared; i.e., although only a single actual hardware/firmware carrier/PN/symbol discriminator capability actually exists physically, N virtual instances of that capability are emulated through time sequencing.

While both a generalized description, as well as an example embodiment, of the present invention has been illustrated and described, it will be appreciated that various other embodiments, adaptations and modifications of the invention will be greatly apparent to those skilled in the art.

WHAT IS CLAIMED IS:

1. In a communications system operating in one or more frequency bands, consisting of various number of channels per band (for a total of N channels), and means for receiving these multiple bands of signals, the improvement in said transceiver comprising:

a system of antenna and RF front end for each said band, a separate RF to IF downconverter for each said band, said IF for each band centered at a succession of frequencies F_c such that the spectra for each band are non-overlapping, with said center frequencies and analog-to-digital converter sampling rate chosen such that one band is centered at baseband, and one or more other bands are centered at a specific relationship with the sampling rate such that each band is individually downconverted to baseband by appropriate selection of tap weight multiplying sequences (such as alternating +/- sequence for the case of F_c equal to one-fourth the sampling rate),

analog-to-digital converter means for converting analog signals to digital signals from said combining means,

digital downconverter means for converting said digital signals to baseband signals and a single digital processor sequentially time shared among all said Bands and channels,

a signal processor connected to said single digital processor responsible for any final signal and/or data processing or formatting,

a signal transmitter of unspecified design details, coupled into the said transceiver antenna path by means of a diplexer device.

2. In a tracking and data relay satellite system operating in the S-band (TDRSS) and in conjunction with a GPS satellite system operating in the L-band, and transceiver means for receiving L-band and S-band signals, the improvement in said transceiver comprising:

a system antenna and RF front end for each said S-band and L-band signal, a separate RF to IF downconverter for each said S-band and L-band signal, said IF for said S-band signal operating at a frequency F_0 and said IF signals for said L-band operating and centered at a frequency F_0 plus a predetermined separation frequency so that the spectra for said S-band and the spectra for said L-band are non-overlapping,

analog-to-digital converter means for converting analog signals to digital signals from said combining means,

digital downconverter means for converting said digital signals to baseband signals and a single digital

processor sequentially time shared among said S-band and L-band signals, respectively,

a GPS navigation processor and a TDRSS data processor connected to said single digital processor,

a TDRSS (S-band) signal transmitter of unspecified design details, coupled into the said TDRSS (S-band) transceiver antenna path by means of a diplexer device.

3. Multi-Band, Multi-Channel Digital Matched Filter (DMF) implementation comprising:

multiple sets (N) of PN-Generators and storage means for maintaining N sets of tap weights within the DMF,

N-stage data delay line which shifts the digital data samples down the line at the baseband sampling rate,

arithmetic circuitry for multiplying alternate taps of said delay line by one of the stored sets of tap weights, pre-multiplied by the +/- or other appropriate downconversion sequence, and summing each of said products, to form a correlation output sample that is a member of the sequence corresponding to a the channel represented by the selected tap weights; sufficient consecutive such sum-of-products samples are thus formed to form the complete correlation epoch function corresponding to the selected channel,

whereby, during acquisition, the tap weights for a single channel are manipulated appropriately such that

consecutive DMF output samples represent correlation epochs associated with a particular PN alignment (offset), and thus an acquisition detection circuit can observe which of the correlation alignments is of sufficient magnitude to indicate the correct PN alignment, and thus transition that channel into tracking,

during tracking, the tap weights are alternated between various channels and manipulated appropriately such that the output sequence from the DMF thus consists of a sequence of sum-of-products samples that are in fact also a sequence of correlation epochs corresponding to each of the channels being tracked,

during ongoing operations in fact both acquisition and tracking operations among multiple channels may be simultaneously taking place using the said techniques.

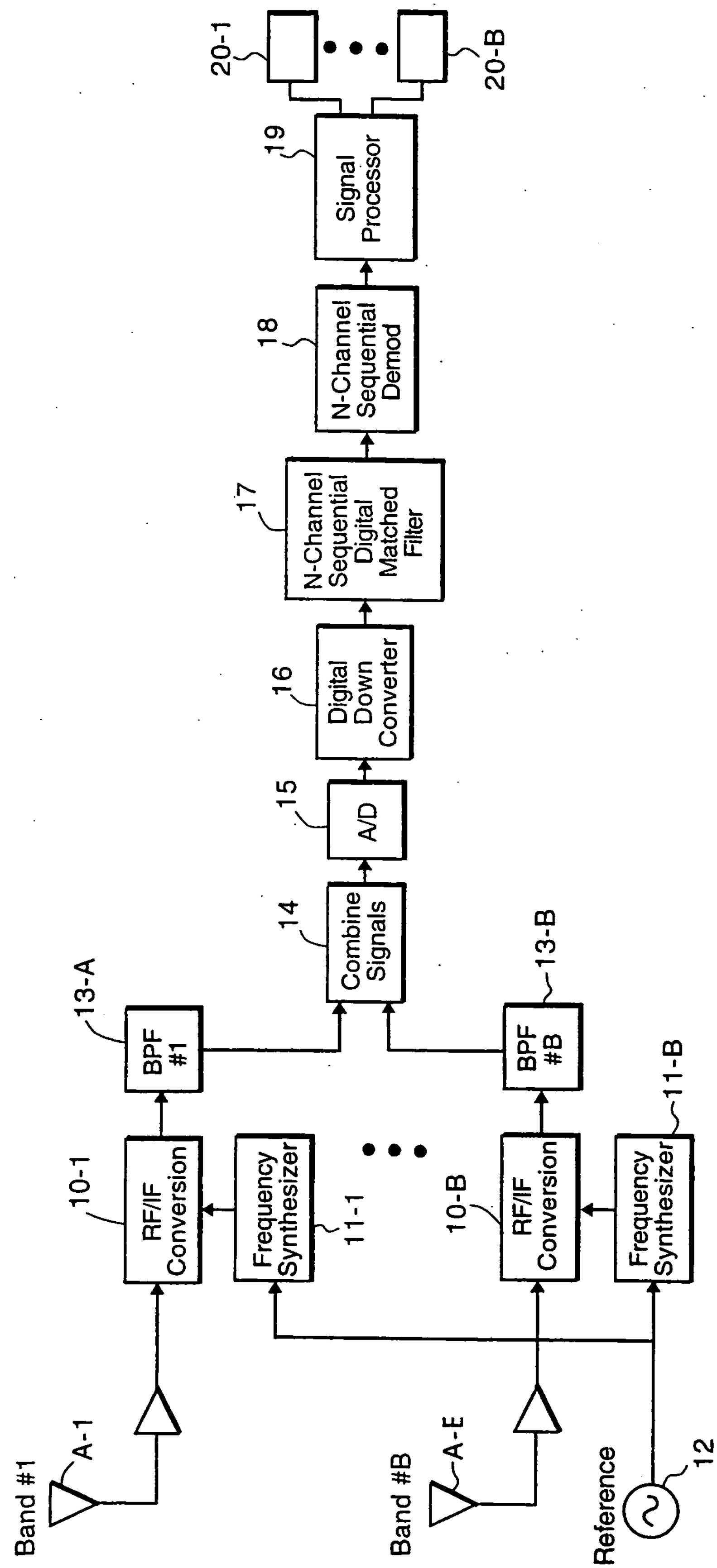
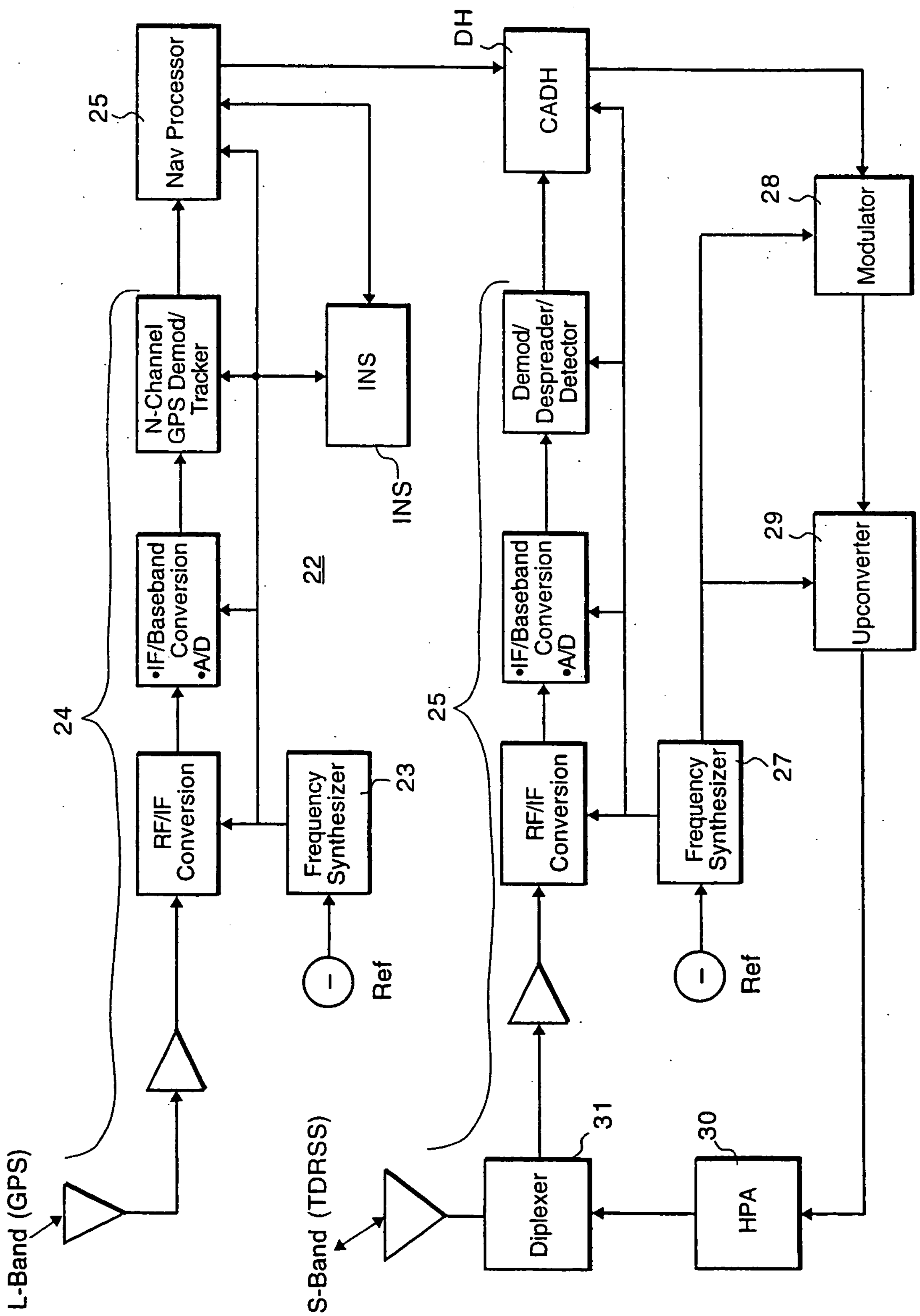

Band #1
A-1
RF/IF Conversion
10-1
Frequency Synthesizer
11-1
BPF #1
13-A
Band #B
A-E
RF/IF Conversion
10-B
Frequency Synthesizer
11-B
BPF #B
13-B
Reference
12
Combine Signals
14
A/D
15
Digital Down Converter
16
N-Channel Sequential Digital Matched Filter
17
N-Channel Sequential Demod
18
Signal Processor
19
20-1
20-B

FIGURE 1

FIGURE 2


L-Band (GPS)
24
RF/IF Conversion
•IF/Baseband Conversion •A/D
N-Channel GPS Demod/ Tracker
25
Nav Processor
INS
INS
22
Frequency Synthesizer
23
Ref
S-Band (TDRSS)
Diplexer
31
25
RF/IF Conversion
•IF/Baseband Conversion •A/D
Demod/ Despreader/ Detector
CADH
DH
Frequency Synthesizer
27
Ref
HPA
30
Upconverter
29
Modulator
28

3/8

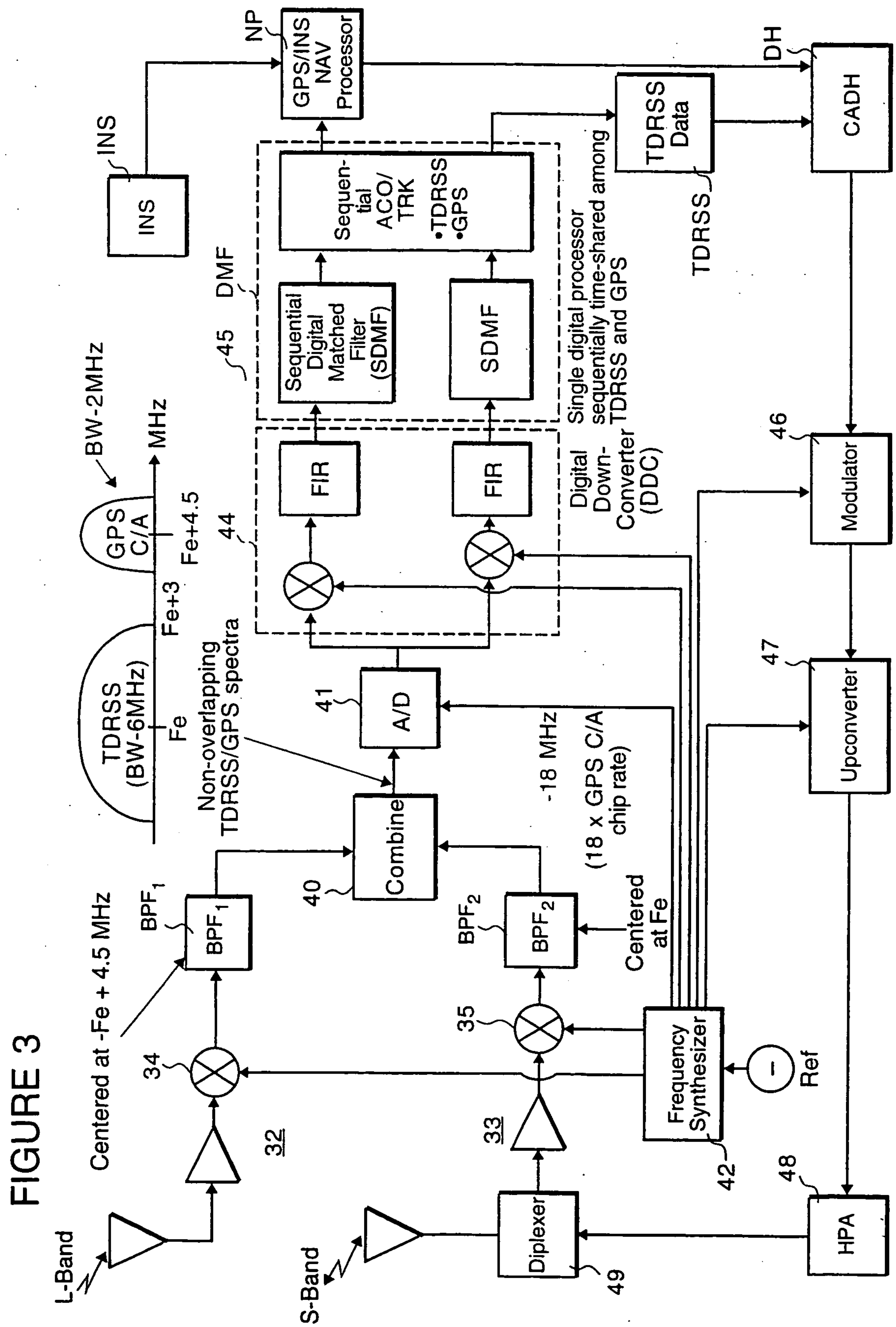
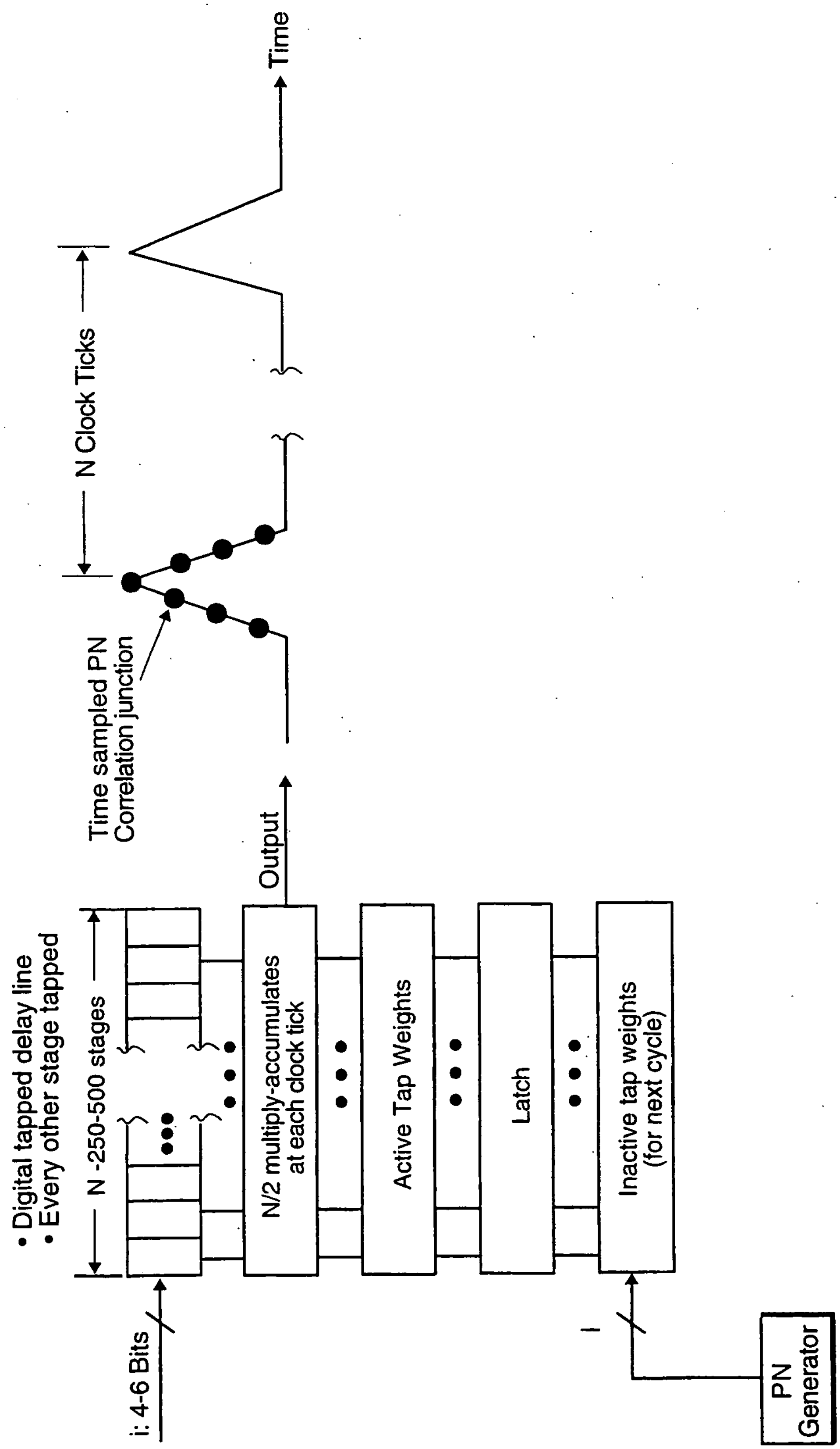


FIGURE 3
L-Band
S-Band
32
33
34
35
Centered at -Fe + 4.5 MHz
BPF1
BPF2
Centered at Fe
40
Combine
Non-overlapping TDRSS/GPS spectra
TDRSS (BW-6MHz)
Fe
Fe+3
GPS C/A
Fe+4.5
BW-2MHz
MHz
41
A/D
~18 MHz (18 x GPS C/A chip rate)
44
FIR
Digital Down-Converter (DDC)
45
DMF
Sequential Digital Matched Filter (SDMF)
SDMF
Sequen-tial ACO/TRK
•TDRSS
•GPS
Single digital processor sequentially time-shared among TDRSS and GPS
INS
NP
GPS/INS NAV Processor
TDRSS Data
TDRSS
DH
CADH
46
Modulator
47
Upconverter
48
HPA
49
Diplexer
42
Frequency Synthesizer
Ref

FIGURE 4


i: 4-6 Bits
• Digital tapped delay line
• Every other stage tapped
N -250-500 stages
N/2 multiply-accumulates at each clock tick
Active Tap Weights
Latch
Inactive tap weights (for next cycle)
PN Generator
Output
Time sampled PN Correlation junction
N Clock Ticks
Time

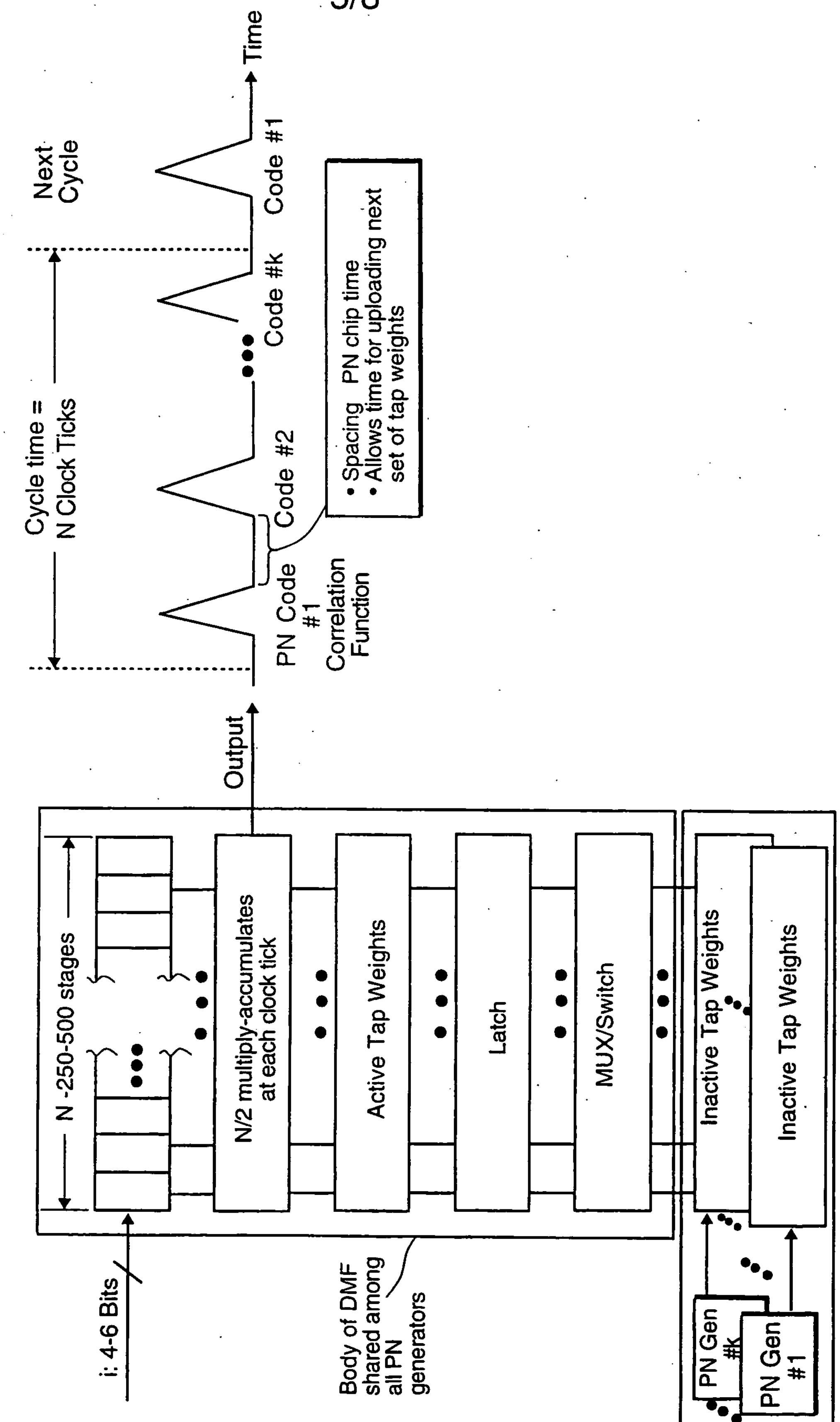

Time
Next Cycle
Code #1
Code #k
Cycle time = N Clock Ticks
Code #2
PN Code #1 Correlation Function
• Spacing PN chip time
• Allows time for uploading next set of tap weights
Output
N -250-500 stages
N/2 multiply-accumulates at each clock tick
Active Tap Weights
Latch
MUX/Switch
Inactive Tap Weights
Inactive Tap Weights
i: 4-6 Bits
Body of DMF shared among all PN generators
PN Gen #k
PN Gen #1

FIGURE 5

FIGURE 6

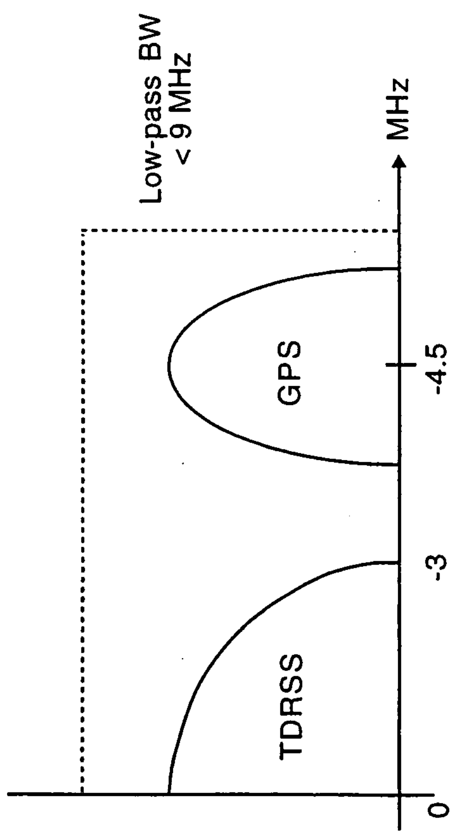


FIGURE 7

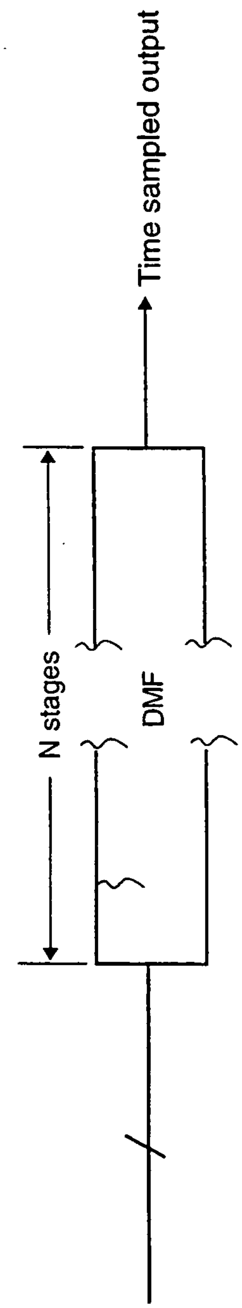
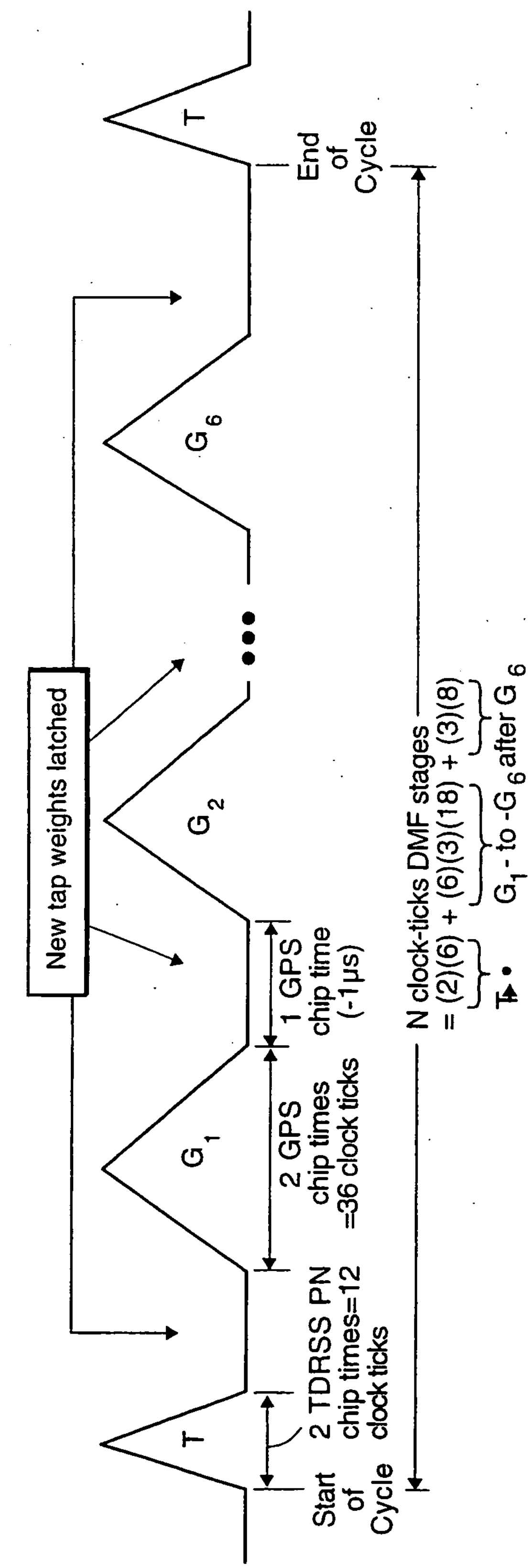


FIGURE 8



New tap weights latched
T
G1
G2
G6
T
Start of Cycle
End of Cycle
2 TDRSS PN chip times=12 clock ticks
2 GPS chip times =36 clock ticks
1 GPS chip time (~1µs)
N clock-ticks DMF stages
= (2)(6) + (6)(3)(18) + (3)(8)
T
G1 - to -G6
after G6

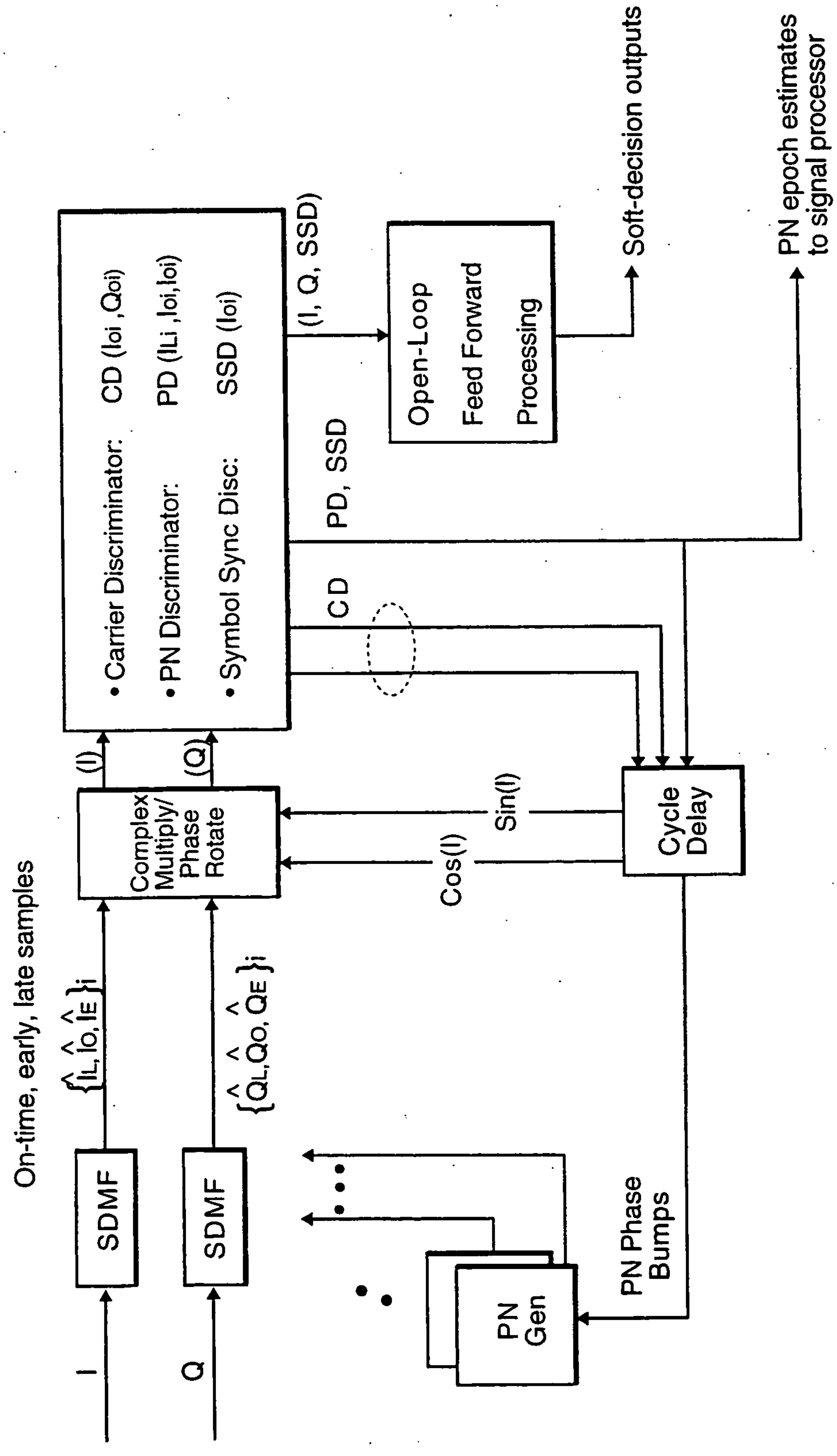

On-time, early, late samples
I
Q
SDMF
SDMF
{IL, IO, IE}i
{QL, QO, QE}i
Complex Multiply/ Phase Rotate
(I)
(Q)
• Carrier Discriminator: CD (Ioi ,Qoi)
• PN Discriminator: PD (ILi ,Ioi,Ioi)
• Symbol Sync Disc: SSD (Ioi)
(I, Q, SSD)
Open-Loop Feed Forward Processing
Soft-decision outputs
PD, SSD
CD
PN epoch estimates to signal processor
Sin(I)
Cos(I)
Cycle Delay
PN Phase Bumps
PN Gen

FIGURE 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/16730

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 1/707
US CL :375/206, 207, 343
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/200, 206, 207, 208, 343

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST (center frequency, sampling rate, baseband, and match filter)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,550,414 A (GUINON et al.) 29 October 1985, col. 9, lines 3-33.	3
A	US 4,785,463 A (JANC et al.) 15 November 1988, col. 5, lines 32-67.	1-2
A	US 5,375,146 A (CHALMERS) 20 December 1994, col. 5, line 41 to col. 6, line 43.	1-2
A	US 5,414,699 A (LEE) 09 May 1995, col. 6, lines 1-68.	3
A	US 5,606,575 A (WILLIAMS) 25 February 1997, col. 5, line 5 to col. 6, line 10.	1-2
A	US 5,638,362 A (DOHI et al.) 10 June 1997, col. 1, lines 34-47.	3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 28 OCTOBER 1999	Date of mailing of the international search report 07 DEC 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer YOUNG TSE Telephone No. (703) 305-4736

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/16730

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,640,416 A (CHALMERS) 17 June 1997, col. 6, line 66 to col. 8, line 6.	1-2
A	US 5,696,762 A (NATALI et al.) 09 December 1997, col. 5, lines 7-14.	3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/16730

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

Group I, claim(s)1-2, drawn to a communications system or a tracking and data relay satellite system operating in one or more freqyency bands.
Group II, claim(s) 3, drawn to a digital matched filter.
The inventions listed as Groups I and II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:
The communications system or the tracking and data relay satellite system in Group I does not require the digital matched filter in Group II. For example, in Group I, an antenna and RF front end, an analog-to-digital converter, a digital down converter, a signal processor or a GPS nevigation processor, and a signal transmitter are provided in the system, however, in Group II, N-stage data delay line and arithmetic circuitry are provided in the digital matched filter which are not required in the system of Group I.